IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Rich, et al.	Group Art Unit: 1756
Appl. No.	:	10/036,198	
Filed	:	December 28, 2001	
For	:	DIFFRACTIVE OPTICAL ELEMENT AND METHOD OF MANUFACTURE	
Examiner	:	Martin J. Angebranndt	

DECLARATION OF PROFESSOR H. JOHN CAULFIELD UNDER 37 C.F.R. § 1.132

United States Patent and Trademark Office
P.O. Box 2327
Arlington, VA 22202

Dear Sir:

I, Prof. H. John Caulfield, declare as follows:

1. I am an expert in holography having authored or edited the following ten books that bear directly on holography:

(a) H. J. Caulfield and Sun Lu, **The Applications of Holography**, John Wiley (1972);

(b) H. J. Caulfield, ed., **Handbook of Optical Holography**, Academic Press (1979), edited by H. J. Caulfield;

(c) H. John Caulfield & Gregory Gheen, eds. **Selected papers on Optical Computing**, SPIE Milestone Series, Vol. 1142, (1990);

(d) Jean Robillard & H. John Caulfield, eds. **Industrial Applications of Holography**, Oxford University Press, New York (1990);

(d) Christopher Tocci and H. J. Caulfield, eds. **Optical Interconnection Foundations and Applications**, Artech House, Boston-London, (1994);

(e) Mustafa A. G. Abushagur and H. John Caulfield, **Selected Papers on Fourier Optics,** SPIE Milestone Series, Vol. Ms. 105, 610 pps., 61 papers, (1995);

(f) Hans Bjelkhagen and H. John Caulfield, **Selected Papers on Holography,** SPIE Milestones Series, (2001);

(e) H. John Caulfield, Jacques Ludman, and J. Riccobono, eds **Holography for the New Millennium**, Springer Verlag, (2002);

(f) H. John Caulfield, ed. **Optical Information Processing: A Tribute to Adolf Lohmann**, SPIE Press. H. John Caulfield, ed (2002);

(g) H. John Caulfield, ed. **The Art and Science of Holography: A Tribute to Emmett Leith and Yuri Denisyuk**, SPIE Press, Bellingham, WA (2004).

2. In addition, I have authored the following twenty-four (24) book chapters are that bear directly on holography:

(a) H. J. Caulfield, "Holography by Shadow Casting," in **Progress in Electro-Optics**, E. Camatini, Ed., Plenum Press, NY (1975);

(b) H. J. Caulfield, "Holographic Spectroscopy," in **Advances in Holography**, Vol. 2, N. H. Farhat, Ed., Dekker, NY (1976);

(c) H. J. Caulfield, "The Applications of Coherent Optical Image Processing in Medicine and Biology," in **Holography in Medicine**, IPC Science and Technology Press, Surrey, England (1976);

(d) H. J. Caulfield, "Holography and Optical Data Processing," **Encyclopedia of Computer Design and Technology**, Vol. 9, J. Belzer, A. G. Holzman, and A. Kent, Eds., M. Dekker, NY, 283 (1978);

(e) D. Casasent and H. J. Caulfield, "Basic Concepts," in **Optical Data Processing**, D. Casasent, Ed., Springer-Verlag, NY (1978);

(f) H.J. Caulfield, "Biomedical Applications of Coherent Optics," in **Optical Data Processing**, D. Casasent, Ed., Springer-Verlag, NY (1978);

(g) H.J. Caulfield, "Holography and Coherent Optics for Industrial Metrology," **SME Technical Paper**, No. 1080-929 (1980);

(h) H. J. Caulfield, R. H. Jackson, and R. P. Brailley, **Holography Works, Museum of Holography**, NY (1983);

(i) Mir Mojtaba Mirsalehi, Mustafa A. G. Abushagur and H. John Caulfield, "Optical and Opto-electronic Computing," **Advances in computers**, Vol. 28, pp. 153-226, Academic Press, Boston (1989) Editor: Marshall C. Yovits;

(j) Mustafa A. G. Abushagur and H. J. Caulfield, "Optical Matrix Computations," **Optical Processing and Computing**, pp. 223-249, Academic Press, Boston (1989) Edited by Henri H. Arsenault, Tomasz Szoplik & Bohdan Macukow;

(k) H. J. Caulfield, "The Holographic Basis for Intelligent Machines," in **Industrial Applications of Holography**, Chapter 1, pgs 3 - 8, Oxford University Press, New York (1990);

(l) H. J. Caulfield, "Holography and Information: Getting Something for Nothing with Light," in **Homageto Galileo**, pp. 37-52, Cooperative Libraria Editrice dell'Universita' de Padova, Padova (1992), P. Mazzoldi., ed., Galileo's "Occhialino" to Optoelectonics, River Edge, NJ, Paolo Mazzoldi, Ed., World Scientific Publishing Co. Pte. Ltd.;

(m) H. I. Jeon, J. Shamir, B. Johnson, H. J. Caulfield, J. Kinser, C. Hester and M. Temmen., "The Use of Fixed Holograms for Massively-Interconnected, Low Power Neural Nets," in **Neural Networks for Perception**, H. Wechsler, Ed., V.II, pp. 282-309, Academic Press (1992);

(n) H. John Caulfield, Joseph Shamir, "Fixed Hologram Neural Networks," **Real-Time Optical Information Processing**, Chapter 7, pp.255-305, Academic Press, Inc., (1994);

(o) J.L. Johnson, H. Ranganath, G. Kuntimad, H. J. Caulfield, "Pulse-Coupled Neural Networks," Neural Networks and Pattern Recognition, Omid Omidvar, and Judith Dayhoff, Eds. (Academic Press, 1998), Chapter 1, pp. 1-56;

(p) H. John Caulfield, Jacques Ludman, and Joseph Shamir, "Fuzzy Metrology," **Fuzzy Systems Theory**, Vol.2. (Academic Press, NY, 1999), Chapt. 26, pp. 747-758;

(q) H. J. Caulfield and J. Shamir, "Holograms of Real and Virtual Point Trajectories," in **Three-dimensional Holographic imaging**, C. J. Kuo and M. H. Tsai eds, Wiley-Interscience, NY (2002), pp. 5-20;

(r) I. Ternovskiy, T. Jannson, and H. J. Caulfield, "Is Catastrophe Analysis the Basis for Visual Perception?," in **Three-dimensional Holographic imaging,** C. J. Kuo and M. H. Tsai eds, Wiley-Interscience, NY (2002), pp. 5-20;

(s) P. Hemmer, S. Shariar, J. Ludman, and H. J. Caulfield, "Holographic Optical Memories," Chapt. 8 in **Holography for the New Millennium**, Springer Verlag, NY (2002), J. Ludman, H. J. Caulfield, and J. Riccobonoi, eds., pp. 179-190;

(t) H John Caulfield, Don O Henderson and Mikhail A Noginov, "Randomness in complex materials." Chapt. 22 in Werner S. Weiglhofer, and Akhlesh Lakhtakia, eds. **Introduction to Complex Mediums for Optics and Electromagnetic**, SPIE Press, Bellingham, WA (2003) pp. 549-590;

(u) Q. Huang and H. J. Caulfield, "Waveguide holography and its applications," in Stephen A. Benton, **Practical Holography**, SPIE Press, Bellingham, WA (2003);

(v) Q. Huang, J. A. Gilbert, and H. J. Caulfield, "Substrate guided-wave holo-interferometry," in Stephen A. Benton, **Practical Holography**, SPIE Press, Bellingham, WA (2003);

(w) J. E. Ludman, J. R. Riccobono, H. J. Caulfield, J.-M. R. Fournier, I. V. Semenova, N. O. Reinhand, P. R. Hemmer, and S. M. Shahriar, "Porous-matrix holography for nonspatial filtering of lasers," in Stephen A. Benton, **Practical Holography**, SPIE Press, Bellingham, WA (2003); and

(x) H. John Caulfield, "Chapter 21. The Bizarre World of the Holographic Brain" in H. John Caulfield, ed. **The Art and Science of Holography: A Tribute to Emmett Leith and Yuri Denisyuk**, SPIE Press, Bellingham, WA (2004);

2. Additionally, I am named as author on two hundred and twenty-one (221) refereed journal papers about one-half of which are on holography.

3. I am named as an inventor on the following fifteen U.S. Patents related to holography:

(a) U.S. Patent 3,433,139 entitled "Electro-Optic Controls For Reflex Cameras" issued in 1969 to H. J. Caulfield;

(b) U.S. Patent 3,540,791 entitled "Simplified Multiple Image Generation" issued 1970 to H. J. Caulfield and S. Lu;

(c) U.S. Patent 3,627,400 entitled "Addressing Holographic Apparatus For Use With Space Division Multiplexed Holograms" issued 1971 to H. J. Caulfield;

(d) U.S. Patent 4,498,740 entitled "Hologram Writer and Method" issued 1985 to H. J. Caulfield;

(e) U.S. Patent 4,510,575 entitled "Method of Writing Holograms" issued 1985 to P. F. Mueller and H. J. Caulfield;

(f) U.S. Patent 4,655,539 entitled "Hologram Writing Apparatus and Method" issued 1987 to H. J. Caulfield and M. Camac;

(g) U.S. Patent 5,295,208 entitled "Multimode Waveguide Holograms Capable of Using Non-coherent Light" issued 1991 to H. John Caulfield et al;

(h) U.S. Patent 5,132,813 entitled "Neural Processor with Holographic Optical Paths and Nonlinear Operating Means" issued 1992 to H. John Caulfield et al;

(i) U.S. Patent 5,056,039 entitled "Holographic interconnect System" issued 1991 to H. John Caulfield et al;

(j) U.S. Patent 5,515,184 entitled "Waveguide Hologram Illuminators" issued 1998 to H. John Caulfield et al;

(k) U.S. Patent 5,854,697 entitled "Waveguide Hologram Illuminators" issued 1998 to H. John Caulfield et al;

(l) U.S. Patent 6,385,474 entitled "Method and Apparatus for High Resolution Detection and Characterization of Medical Pathologies" issued 2002 to J. D. G. Rather et al;

(m) U.S. Patent 6,540,678 entitled "Real Time Three Dimensional Acoustoelectronic Imaging and Characterization of Objects" issued 2003 to J. D. G. Rather et al;

(n) U.S. Patent 6,639,733 entitled "High Efficiency Non-imaging Optics" issued 2003 to Juan C. Minano et al; and

(o) U.S. Patent 6,728,567 entitled "Method and Apparatus for High-resolution Detection and Characterization of Medical Pathologies" issued 2004 to J. D. G. Rather et al;

4. I have written many popular articles in the field of holography including the most widely read article any scientist has ever written – the 1984 National Geographic cover story "The Wonder of Holography" that was read by more than 25,000,000 people.

5. My work in the field of holography has been noted in Scientific American, IEEE Spectrum, American Way, and Delta Sky.

6. I have written chapters on holography for Marcel Dekker's **Encyclopedia of Modern Optics**.

7. I have authored the first paper in the first issue of a new journal, **Holography and Speckle**.

8. I chaired the first Gordon Research Conference on holography and have chaired holography conferences for OSA, SPIE, and IEEE.

9. I am on the editorial boards of the only two holography journals **Holography and Speckle** and **Holography News**.

10. In 1994, I won the Dennis Gabor Award Honoring the Nobel Prize winning inventor of holography, which is given for major contributions to the field.

11. I have reviewed the above-referenced patent application together with the Office Action mailed September 16, 2003, the Amendment by Applicant dated December 16, 2003, as well as the Office Action mailed March 22, 2004, and I am familiar with these documents.

12. In addition, on May 17, 2004, I visited Wavefront Technology, Inc. "Wavefront" to learn about Wavefront's method of fabricating a diffractive optical element. At Wavefront's facilities, I interacted at length with the inventors and the materials scientists. I witnessed the method being performed and questioned and understood each step. I examined the final product. On the basis of my expertise going into these meetings and what I learned at these meetings, I feel extremely confident in the correctness of the observations set forth herein.

13. Wavefront has demonstrated a method wherein a layer of curable material is physically contacted with a surface relief pattern (such as a two-dimensional surface relief hologram) thereby imprinting the pattern on the surface of the layer of curable material. The curable material comprising, for example, liquid crystal, is cured and diffractive features comprising refractive index variations are thereby formed in the layer of curable material that correspond to the pattern. To form these diffractive features energy is propagated through the medium having the surface relief pattern on a surface thereof and from the medium into the layer of curable material to produce the diffractive features through non-interference effects. Volume holograms may be produced by this method.

14. A hologram is defined as a tranducer that operates on wavefronts, e.g., A and B, to provide the following outputs.

Input	Output
A	B
B	A
A*	B*
B*	A*

The wavefronts A* and B* correspond to perfectly direction and amplitude reversed wavefronts (referred to as "phase conjugate" beams). The Wavefront method may be employed to create diffractive optical elements that conform to the above-referenced input/output mapping, thus, by definition producing holograms.

15. Wavefront's method creates volume holograms by forming diffractive features comprising refractive index variations in the layer of curable material. This conclusion is supported by two independent facts. First, the holograms formed by Wavefront's method are much more efficient than 33.9%, which is the theoretical limit for a thin (surface) hologram comprising solely surface relief features. Second, surface holograms can be rendered ineffective by index matching the surface hologram with an index matching liquid. The structures produced by Wavefront, however, remained highly efficient even after index matching.

16. In my opinion, the diffractive features in the layer of curable material can be produced using non-interferometric effects by physically contacting a layer of curable material with a surface relief pattern and curing the curable material by propagating energy through the surface relief layer as set forth in the application. The concept of interference does not enter into the definition of a hologram, which is defined above as a transducer that operates on wavefronts, e.g., A and B, to provide a particular input/output mapping. Indeed, many holograms are made without interfering beams. Examples of non-interferometrically generated holograms include computer generated or even hand drawn holograms. Kinoform diffusers are a special kind of on-axis hologram made from laser speckle. I invented kinoform diffusers about 35 years ago. Kinoform diffusers behave as though the kinoform diffusers were made using a first non-diffuse beam and a second diffuse beam, however, kinoform diffusers are actually made by laser speckle recording and not interference.

17. The conclusion that Wavefront's diffractive optical elements are formed through non-interferometric effects is proven by index matching the layer of curable material with the medium having the surface relief pattern physically contacted thereto. In Wavefront's process, even in the case where the medium having the surface relief pattern is index matched with the layer of curable material such that no diffraction and consequently no diffracted beam is available to produce interference, the process yields an efficient volume diffractive optical element. Refractive index features comprising refractive index variations are formed in the layer of curable material.

18. Further evidence indicates that diffractive features in the layer of curable material can be produced using non-interferometric effects. For example, UV lamps that are not temporally coherent and are broadband may be employed to cure the layer of curable material. This broadband temporally incoherent energy is propagated through the medium having a surface relief pattern on a surface thereof into the layer of curable material to produce the diffractive features through non-interference effects. In general, attempts to produce interference with broadband temporally incoherent energy suffer low contrast. The product yielded by Wavefront's process, however, demonstrates high optical efficiency. This high optical efficiency may be a result of index of refraction variations that extend deeper (e.g. greater than 5 or 10 microns) into the volume of the diffractive optical element than can be provided by interference using a broadband incoherent light source. As a result, the diffractive features comprising refractive index variations possess high contrast in contradiction with the product one would reasonably expect that is produced using interference from broadband incoherent energy sources.

19. Accordingly, I believe that Wavefront's method of using a medium having a surface relief pattern on a surface thereof to manufacture a volume diffractive optical element through non-interference effects is operable. I witnessed the entire process being performed. The process works remarkably simply and fast.

20. I believe that this method of manufacturing a diffractive optical element is of practical value. This method has enabled Wavefront to produce what I believe are the lowest cost high efficiency volume holograms in the world.

21. My opinion is that this method is new, surprising, and non-obvious. I have a good overview of the field and as an expert in the field, people from around the world routinely relate to me their latest inventions. The approach Wavefront has invented and reduced to practice is totally new to me and quite revolutionary. I myself have sought ways to accomplish this goal for years without success. Fabricating diffractive optical elements having diffractive features comprising refractive index variations from surface relief pattern through non-interference effects

is completely new and surprising to me. Wavefront has not simply improved prior technology, rather Wavefront's approach is different in kind from any technique known to me.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or patent issuing therefrom.

Dated: July 5, 2004 By: _____
Prof. H. John Caulfield

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